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PRELIMINARY FLIGHT EVALUATION
OF A PAINTED DIAMOND ON A RUNWAY
FOR VISUAL INDICATION OF GLIDE SLOPE

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16. Abstract <p>A diamond sized to appear equidimensional when viewed from a 3.6° glide slope was painted on the end of a small general aviation airport runway, and a series of flights was made to evaluate its usage as a piloting aid. Twenty pilots each flew five approaches and landings with the diamond and five without it.</p> <p>The pilots could detect and fly reasonably close to the glide slope projected by the diamond. The flight path oscillations that were recorded during approaches using the diamond were not significantly different from the oscillations that were recorded without the diamond; the difference that did exist could be attributed to converging on a known projected glide slope in one case, and flying an unknown, random glide slope in the other. The results indicated that the diamond would be effective as a means of intercepting and controlling a predetermined glide slope. Other advantages of the diamond were positive runway identification and greater aim point visibility. The major disadvantage was a tendency to overconcentrate on the diamond and consequently to neglect cockpit instruments and airport traffic.</p>					
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PRELIMINARY FLIGHT EVALUATION OF A PAINTED DIAMOND ON A RUNWAY FOR VISUAL INDICATION OF GLIDE SLOPE

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INTRODUCTION

A statistical review of general aviation accidents (ref. 1) shows that many accidents are caused by pilot error during takeoff and landing. The landing approach task is one of the most difficult tasks encountered by the private pilot. It is especially difficult at an unfamiliar airport where the topography beyond the end of the runway tends to mislead the pilot in regard to his approach angle. Misleading glide-slope information has caused some pilots to land short of the runway and others to land so long that the aircraft could not be stopped on the runway.

Studies by Kelly and Bliss (ref. 2) indicated that observers can discern differences in diamond shapes that would constitute deviations of less than 0.2° from a specific glide slope. If such deviations are detectable when viewing a diamond painted on the runway, it should be possible to fly glide slopes accurately regardless of terrain or runway slope.

Several airports in Humboldt County in northern California replaced the conventional "dashed" runway centerline with a string of painted white diamonds as a pilot aid in finding the airport. The diamonds were 22.9 meters (75 feet) long and 3.04 meters (10 feet) wide, and they were separated longitudinally by 22.9 meters (75 feet) (ref. 3). Pilots using these runways seemed to like the diamonds, and to feel that their performance during approach and landing was improved, but they could not explain why this was so. A study of these diamonds conducted by the Federal Aviation Administration (FAA) (ref. 4) was for a specific application and did not exploit the potential of the diamond as a visual flight rules (VFR) landing aid.

Consequently, a cursory investigation of the benefits that might be derived from a large single diamond painted on a runway was conducted by the NASA Flight Research Center at a small general aviation airport at Rosamond, Calif. Of particular interest was the use of glide-slope information projected by the diamond. A group of 20 FAA-certified pilots representing a cross section of the general aviation community flew approaches, with and without the diamond, in a Cessna 150 aircraft. The flight tests took place during the predominantly windy months of March and April 1972.

Physical quantities in this report are given in the International System of Units (SI) and parenthetically in U.S. Customary Units. The measurements were taken in Customary Units. Factors relating the two systems are presented in reference 5.

DESCRIPTION OF EXPERIMENT

Objectives

A flight test program was performed to determine the usefulness of a diamond painted on a runway as an aid in maintaining a specific glide slope. The diamond (fig. 1) was sized so that it appeared equidimensional when viewed from an extension of the runway centerline at a specific glide slope; that is, it was as long as it was wide (fig. 2(a)). When viewed from above the glide slope, the diamond appeared longer than it was wide (fig. 2(b)), and when viewed from below, it appeared shorter (fig. 2(c)). By flying the approach in such a manner that the diamond remained equidimensional, a pilot could maintain a given glide slope. It was desired to determine to what degree of accuracy the glide slope could be flown using the diamond as a visual approach slope indicator in a real-life situation by a representative sample of general aviation pilots. It was believed that performances close to those achieved in laboratory experiments such as described in reference 2 might be obtained.

It was also desired to determine how steady the pilot held his glide slope without the diamond, but with reference to a line (fig. 3) as an aim point.

It is known that small general aviation runways are often difficult to identify from the air, especially in congested urban areas. The distinctive diamond shape should improve runway identification from the air. It was believed that flight tests might indicate an improvement in this area. It was also believed that the diamond would be useful as an aim point; that is, the diamond might prove to be more visible than an unmarked runway threshold, and for that reason alone improve the ability of the pilot to control the glide path to that point.

It was questionable whether the added task of attempting to control the glide-slope angle through the visual appearance of the diamond would increase the pilot's workload significantly, especially in those cases where the test subjects had relatively little flight experience. Consequently, questionnaires were formulated to determine to what extent, if any, this was true.

Test Procedure

The flight test data were gathered during two separate series of flights. The first series was flown with the diamond painted on the runway threshold, and the second set of flights was flown with a white line in place of the diamond. Twenty pilots flew approaches, and each pilot flew five data approaches in each series.

The diamond used was positioned and sized as shown in figure 1. These dimensions provided a diamond that would appear as high as it was wide when viewed from a slant range of 1524 meters (5000 feet) at an angle of 4° with respect to the plane of the diamond. Because of a 0.4° slope in the runway, the projected glide-slope angle was 3.6° .

The test aircraft was a Cessna 150, a light, single-engined, two-place aircraft widely used as a trainer. This aircraft was chosen because it is representative of the

general aviation class of aircraft. The test subjects were volunteer general aviation pilots who were chosen to represent a reasonable cross section of experience. Information about the subject pilots is given in appendix A.

The test approach flown was not typical for small general aviation airport operations, but is used occasionally at traffic controlled airports; it consisted of a long (3540-meter (2.2-mile)), straight-in, constant-glide-slope approach, followed by a normal flare and full-stop landing. The pilots initiated their approaches over a designated landmark at an altitude of 243.8 meters (800 feet) above ground level. This position was on a 4° glide slope and approximately 24 meters (80 feet) above the glide slope projected by the diamond. A radio report was made by the pilot when he passed through that point.

For the first set of approaches the pilot was instructed to use the diamond as an approach aim point and to try to keep the diamond equidimensional. Approach speed, flap settings, and so forth were left to the pilot's discretion. He was instructed to discontinue the use of the diamond at the point in the approach where flare was initiated. For the second set of approaches, without the diamond, the pilot was instructed to maintain a constant glide slope using a line across the runway where the center of the diamond had been (fig. 3) as an approach aim point. This line was 6.10 meters (20 feet) long and 1.52 meters (5 feet) wide. Again, the aircraft configuration was left to the pilot.

Data Acquisition

Data were collected on glide slope, touchdown dispersion, and wind conditions, and qualitative data were obtained from pilot questionnaires.

Glide-slope data. - The approach glide-slope angle was recorded by using a manually operated optical tracking device and a recorder. The optical tracking device (fig. 4) consisted of a gunsight attached to a camera tripod. The device was placed adjacent to the diamond just off the runway and in line with the glide slope. Movement of the gunsight in the vertical plane caused a corresponding movement of a shaft on a potentiometer. A voltage output from the potentiometer was recorded on one channel of a two-channel strip recorder. The other channel was used to record events from a hand-held switch, which was depressed to signify the times when the aircraft passed over the initial checkpoint and the runway threshold. The recorder and voltage source are shown in figure 5.

Touchdown dispersion. - The touchdown distance from the middle of the diamond, or the aim point line for the second series of flights, was obtained for each landing. Markers were placed along the runway at 15.24-meter (50-foot) intervals. Touchdown distances were estimated and recorded by an observer after each landing.

Wind conditions. - Wind direction and velocity at the side of the diamond were recorded for each landing. The portable measurement system that was used is shown in figure 6.

Questionnaires. - Each test subject filled out a questionnaire after each flight. The questionnaire in appendix B was filled out immediately after the pilot completed

the approaches with the diamond, and the questionnaire in appendix C was filled out immediately after he completed the approaches without the diamond.

RESULTS AND DISCUSSION

Weather conditions during the tests varied from calm, smooth air to crosswinds of 15 knots with gusts to 25 knots and moderate turbulence. At times wind shear existed at altitude which required approximately 15° of wind correction angle in one direction and up to 15° of correction in the opposite direction during the approach, where the surface wind was light and variable. The pilots were requested to comment on turbulence, but since no rating scale was provided, the comments could not be compared. As a result, no attempt was made to sort the data for comparisons of performance under different weather conditions.

A time history of a typical approach made using the diamond for visual approach slope indication is shown in figure 7. Histograms and values for statistical data were obtained by tabulating the average values for 5-second intervals from the time histories. The data from the last 10 seconds of the approach were not used because flare was initiated during this period. A histogram of glide-slope position for all the approaches made using the diamond is shown in figure 8. A histogram of all the approaches made without using the diamond is shown in figure 9.

In all cases, the initial approach point was on a 4° glide slope, which was approximately 24 meters (80 feet) above the glide slope projected by the diamond. The data in figure 8 show that the pilots recognized this situation, and their convergence with the diamond reference resulted in a glide slope with a mean angle of 3.54° . Without the diamond, the pilots were instructed to fly a constant glide slope from the start point. Figure 9 shows that the pilots' estimation of that glide slope had a mean angle of 4.12° . The fact that the pilots were able to derive some information from the diamond was also confirmed by answers to question 2 in appendix B, which indicated that, without exception, all the pilots were able to detect changes in the shape of the diamond, and hence the glide slope projected by the diamond. Some subjects commented that it seemed easier to detect diamond shape change when above the glide slope than when below it. However, the mean glide slope flown with the diamond was only 0.06° below the nominal, so this factor did not appreciably affect the results. The results indicate that the diamond would be effective as a means of intercepting and controlling a predetermined glide slope.

The standard deviation is the variance or oscillation about a mean value and is indicative of the resolution of the system. For all diamond approaches, the standard deviation was 0.77° , which was not significantly different from the standard deviation (0.71°) for all nondiamond or normal approaches. This was not surprising when one considers that during normal VFR approaches the pilot does not attempt to maintain a particular nominal glide slope, but makes adjustments in the airplane's power and flaps (and therefore glide slope) until the glide slope appears to terminate on the runway threshold. Thus the pilot flies an unknown, random glide slope. The standard deviation of 0.2° as reported in reference 2 was not realized during these tests.

It is well known among pilots that a good approach generally results in a good landing. A good approach may be defined as one that ends at flare initiation with the vehicle at the optimum altitude, speed, and attitude for making a landing. If these variables were at the same nominal values at the end of each approach (assuming constant wind conditions), the touchdown variance would be an expected minimum. The average of the touchdown variance for the landings with the diamond was 131 meters (430 feet). Without the diamond, it was 128 meters (419 feet). Therefore it was concluded that landing performance was not changed.

Although the airport at Rosamond was not difficult to see from 3540 meters (2.2 miles) away, it could be difficult for pilots unfamiliar with the area to identify. The diamond made the runway easy to see and identify because of the large white area of the diamond on the black asphalt runway. The airport operator reported that occasionally just before sundown, landing west, the runway had been difficult to identify and that some airplanes had landed on the adjacent taxiway. With the diamond, however, the runway threshold was clearly identified.

It was believed that the diamond would provide pilot confidence in terms of obstacle clearance during the approach. Power lines are located approximately 365 meters (1200 feet) from the approach end of the runway. When the subject pilots were questioned about the power lines, all were aware of the presence of the lines and some were not concerned about wire clearance when using the diamond. The obstacle clearance confidence factor was not borne out in the data; however, this may be because the glide slope flown provided sufficient obstacle clearance.

Responses to the questionnaires indicate that the pilot workload was not increased significantly by the use of the diamond. A few pilots indicated that the task of flying the aircraft was so difficult that they had no time for using the diamond. These pilots were near the extreme lower end of experience, however. Most of the subject pilots indicated that they found the diamond useful and all said they would use it if it were available at airports.

Pilot fixation on the diamond was thought to be a potential problem. Some pilots reported increased workload using the diamond during approaches; however, at flare distance the diamond became noticeably distorted, and the transition to flare and landing occurred without noticeable pilot fixation problems.

Some disadvantages of using the diamond were also identified (question 8, appendix C). Seven pilots reported that they tended to overconcentrate on judging the shape of the diamond, which resulted in a tendency to neglect the cockpit instruments and airport traffic.

CONCLUSIONS AND RECOMMENDATIONS

A flight test program was conducted to investigate the benefits that might be derived from a large diamond painted on a runway. Of particular interest was the use of glide-slope information projected by the diamond. All the pilots indicated in a questionnaire that they were able to detect changes in the shape of the diamond, and hence the glide slope projected by the diamond. The test data showed that pilots flew

average glide slopes reasonably close to the glide slope projected by the diamond, and that their oscillations about the projected glide slope were not significantly different from the oscillations they made during a normal approach. The difference that did exist could be attributed to converging on the known projected glide slope in one case, and flying an unknown, random glide slope in the other. The results indicated that the diamond would be effective as a means of intercepting and controlling a predetermined glide slope.

Most of the pilots found the diamond to be useful and said they would use it if it were available at airports. Furthermore, the diamond improved runway identification and provided a more visible aim point for approaches. Pilot workload was not significantly increased, and no evidence of fixation on the diamond was observed.

Some disadvantages of the diamond were identified. The most significant was a tendency to overconcentrate on judging the shape of the diamond, which resulted in a tendency to neglect cockpit instruments and airport traffic.

As a result of this evaluation, it was recommended that further studies of the diamond be conducted. These might include studies of (1) intercepting and tracking the projected glide slope from level flight, (2) flight path and touchdown dispersions under constant weather conditions, (3) use of the diamond in a conventional traffic pattern, (4) use of the diamond at other airports, and (5) use of lights to outline the diamond at night.

Flight Research Center
National Aeronautics and Space Administration
Edwards, Calif., March 16, 1973

APPENDIX A

PILOT INFORMATION

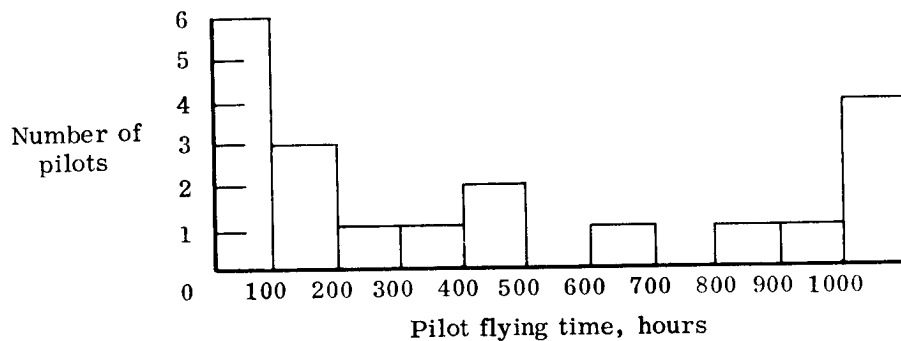
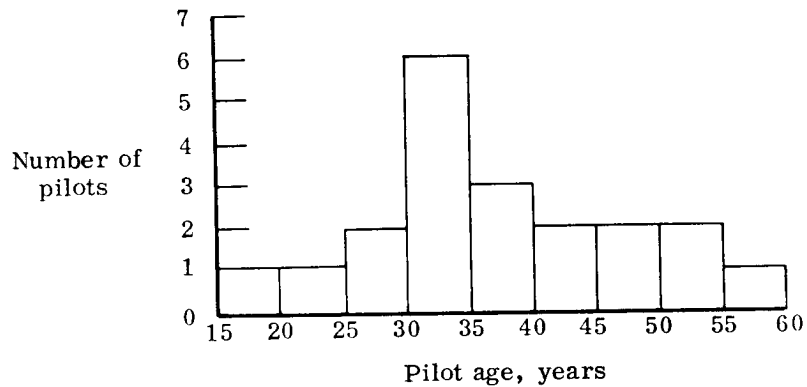
The subject pilots were required to fill out a questionnaire regarding their piloting experience. The validity of each pilot's certificate, rating, medical certificate, and radio operator's permit was visually checked. Each pilot was allowed 2 hours of flying at the test site in the test airplane before the start of the tests. This was for the purpose of complying with the airport operator's minimum proficiency requirements and with the Federal Air Regulations regarding recent flight experience. All test flights were solo with the exception of a few made with a research engineer as an observer. A summary of the information obtained from the questionnaires is as follows:

Type of certificate -

Private	14
Commercial	6

Rating -

Airplane single engine land . .	20
Airplane multiengine land . . .	2
Glider	3
Helicopter	1
Instrument	3
Instructor	2



APPENDIX B

VISUAL AID PILOT QUESTIONNAIRE AND RESPONSES
(WITH DIAMOND)

1. Was the diamond clearly visible when you started descent?

Yes - 20
No - 0

Comments: (2) Difficult to detect detail.

2. Were you able to detect changes in the shape of the diamond?

Yes - 20
No - 0

Comments: (5) Changes were small, especially when far away.
(2) On high side, yes; less noticeable on low side.

3. In any of your approaches (prior to flare) did you experience any large deviations from the equidimensional diamond shape?

Yes - 9
No - 11

Comments: (3) Only at end of approach.
(1) Due to turbulence.
(1) Easy to get back to proper position.

4. Did you have any difficulty in lining up and staying lined up with the runway during the approaches?

Yes - 4
No - 16

Comments: (2) Wind effects.

5. Did you feel you were busy enough flying the airplane that you could not concentrate on the shape of the diamond?

Yes - 3
No - 17

Comments: (2) Due to turbulence.
(1) Concentration on diamond detracted from flying the airplane--controlling airspeed, etc.

6. Did your airspeed stay reasonably constant during the approaches?

Yes - 17

No - 3

Comments: (1) Required power changes.

(1) Turbulence effects.

(1) Deliberately changed during approach.

7. Did your concentration on the diamond cause you to start flare late on any approach?

Yes - 2

No - 18

Comments: (1) Felt I had excessive speed during flare due to tail wind.

8. Do you feel this approach aid would be useful to general aviation pilots in general?

Yes - 19

No - 1

Comments: (3) For power approaches, straight-ins.

(1) Especially for lining up with runway.

(2) Feel learning task is involved.

(1) For aim point only.

(1) Undecided.

(1) On calm days only due to concentration required.

9. If it were available, would you use it?

Yes - 20

No - 0

Comments: (1) Only on long, low approaches.

10. Do you have any comments about using the diamond not covered in previous questions?

(1) Moving the head to different positions helped.

(1) Bothersome to match diamond at low rpm.

(1) Wonder if diamond would be useful in power failure operation.

(1) Changes varied from small at beginning of approach to too rapid at flare point.

(1) In turbulent air, if you viewed diamond as shorter than square you would be far too low.

(1) Need power for this diamond approach.

(1) Appeared too insensitive when below glide slope.

(1) Changes only noticeable when somewhat off glide slope.

(1) Would be time-consuming at small airports.

(1) Makes a good aim point.

(1) Very good aid. I normally have trouble on long straight-in approaches, but this really helps.

APPENDIX B - Concluded

- (1) Gives pilot a lot of confidence.
- (1) Need larger diamond.
- (2) Some tendency to overconcentrate on diamond.
- (1) Always experienced a definite height dimension over width dimension during approaches.

APPENDIX C

VISUAL AID PILOT QUESTIONNAIRE AND RESPONSES

(WITHOUT DIAMOND)

1. Did your approaches and landings seem better than those you made with the diamond?

Yes - 6
No - 11
Same - 3

Comments: (1) Had to work harder.
(3) Due to improved weather.
(1) Could still see diamond outline, which helped.

2. Would you say that your recent flights (with the diamond) caused an improvement in today's performance?

Yes - 11
No - 9

Comments: (3) Because of practice; not sure diamond a factor.
(1) Had some idea of how runway should look for this kind of approach.

3. Did you have any difficulty in getting and staying lined up with the runway during the approaches today?

Yes - 7
No - 13

Comments: (5) Weather effects.

4. Did you have to make any "last-minute" large changes in power or flaps just prior to landing?

Yes - 8
No - 12

Comments: (1) That was my intent.
(2) Weather effects.

5. Did you have any difficulty controlling your airspeed during approaches?

Yes - 5
No - 15

Comments: (5) Weather effects.

APPENDIX C - Concluded

6. Did you find it easier to make approaches and landings without the diamond?

Yes - 3
No - 14
Same - 3

Comments: (1) Diamond required extra concentration.
(1) Diamond aided runway lineup.

7. Now that you have flown with and without the diamond, were there any advantages of having the diamond on the runway?

Yes - 19
No - 1

Comments: (1) Gives gross indications of high and low, left and right.
(1) It calibrated me for that glide slope and conditions.
(3) Aim point.
(1) I believe I could hold glide slope using the diamond even with a severe crab angle.
(2) For an unfamiliar runway.

8. Were there any disadvantages?

Yes - 8
No - 12

Comments: (7) Tended to overconcentrate.
(1) Deviations too small.
(1) Not sensitive enough--only good for deviations of greater than 100 feet.
(1) Requires unusual approach--straight in.

9. Were the power lines near the end of the runway more "on your mind" when using the diamond, or without it?

With diamond - 2
Without diamond - 4
Same - 14

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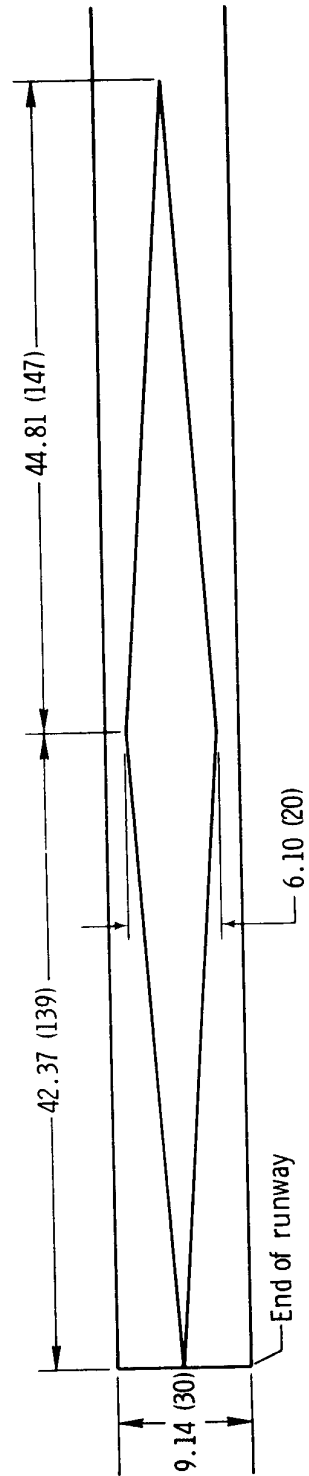
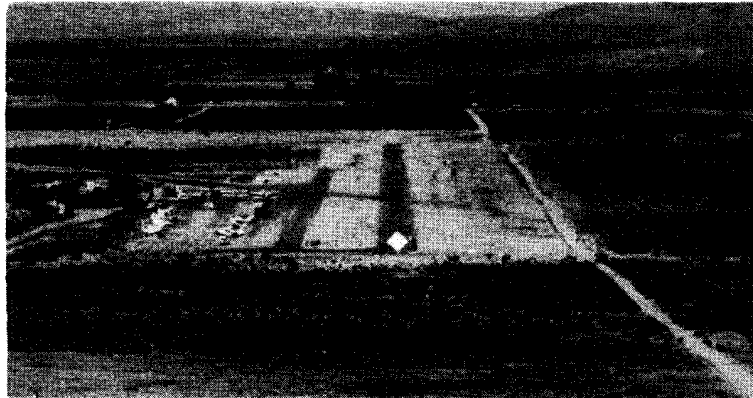
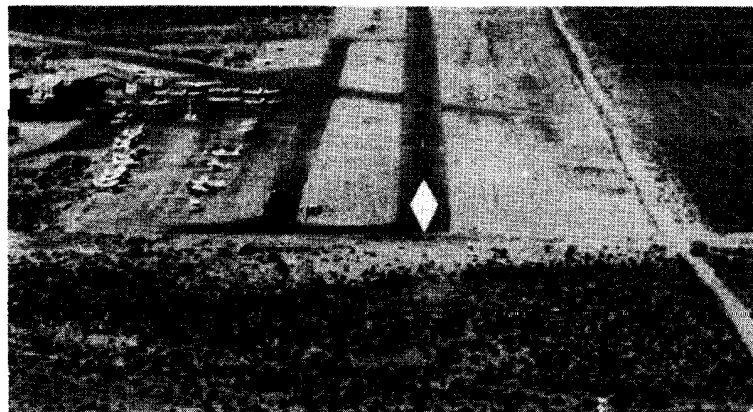


Figure 1. The diamond painted on the end of the runway at Rosamond Airport. Dimensions are in meters (feet).



(a) On the glide slope.

E-24416



(b) Above the glide slope.

E-24417



(c) Below the glide slope.

E-24421

Figure 2. View of painted diamond from the air.

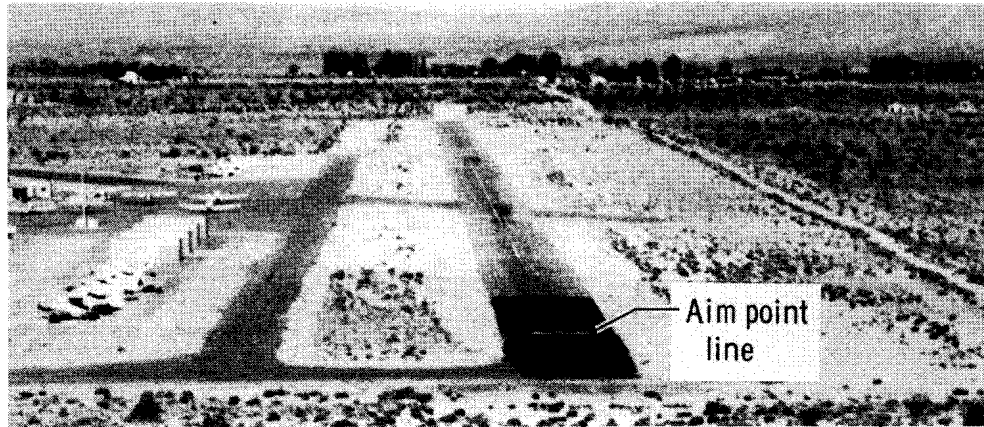


Figure 3. Line on runway threshold used as an aim point.

E-24882

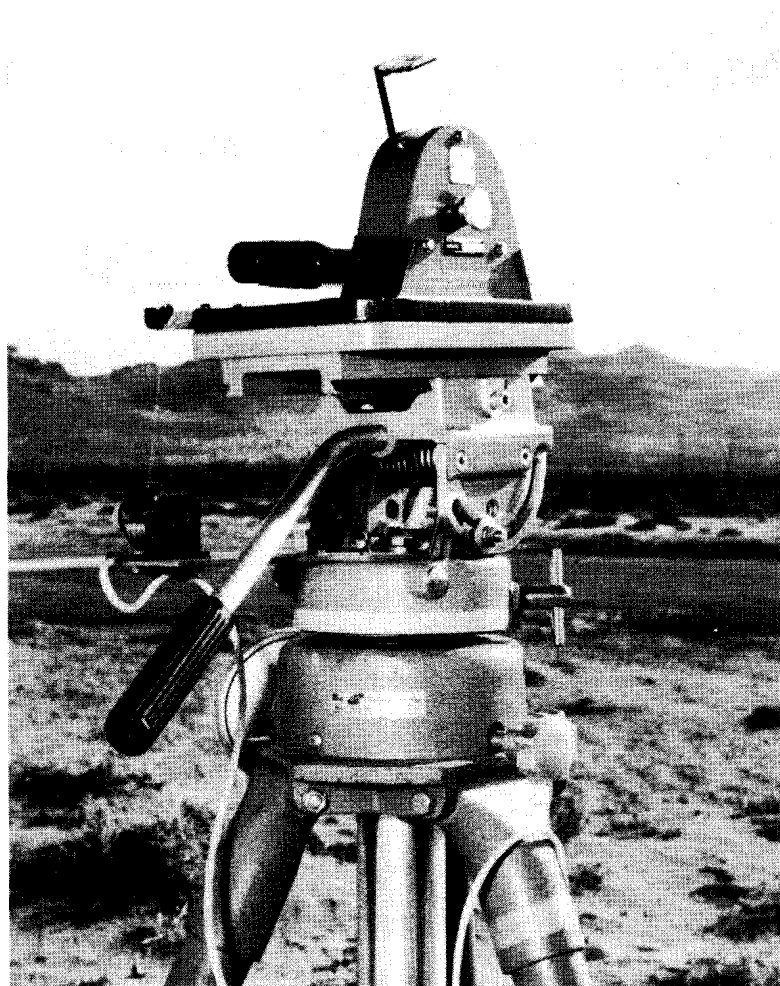


Figure 4. Optical tracking device used to measure glide slope.

E-24387

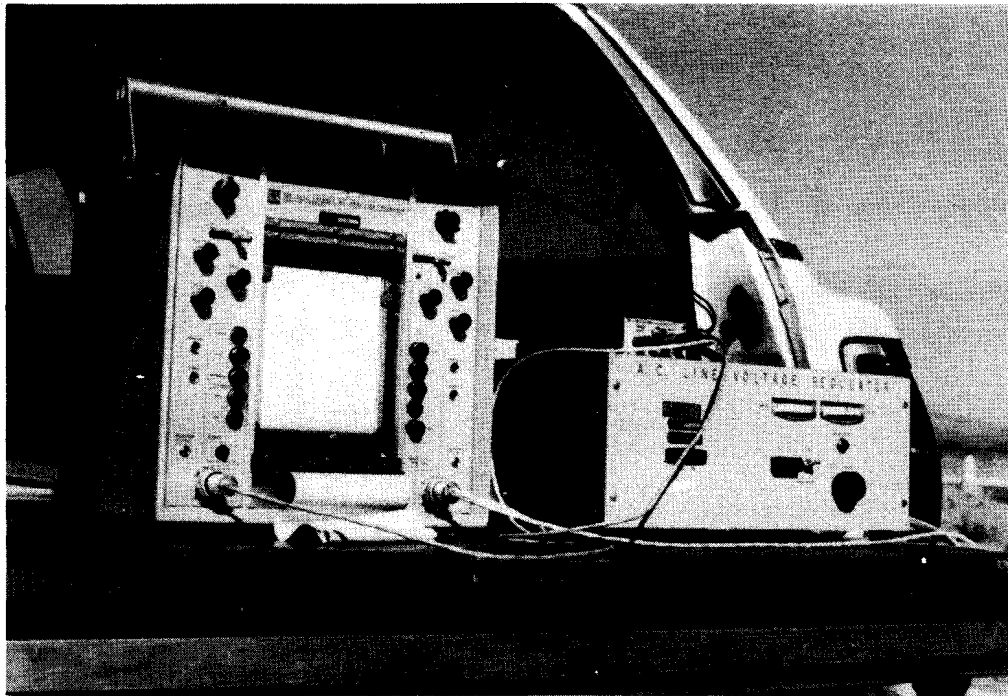


Figure 5. Recorder and voltage source used for glide-slope tracking. E-24381

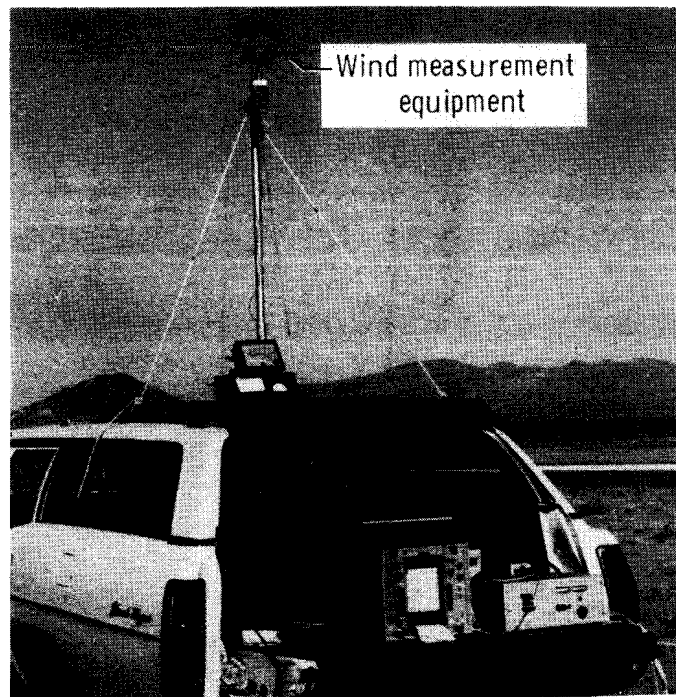


Figure 6. Portable measurement system used to record wind conditions. E-24379

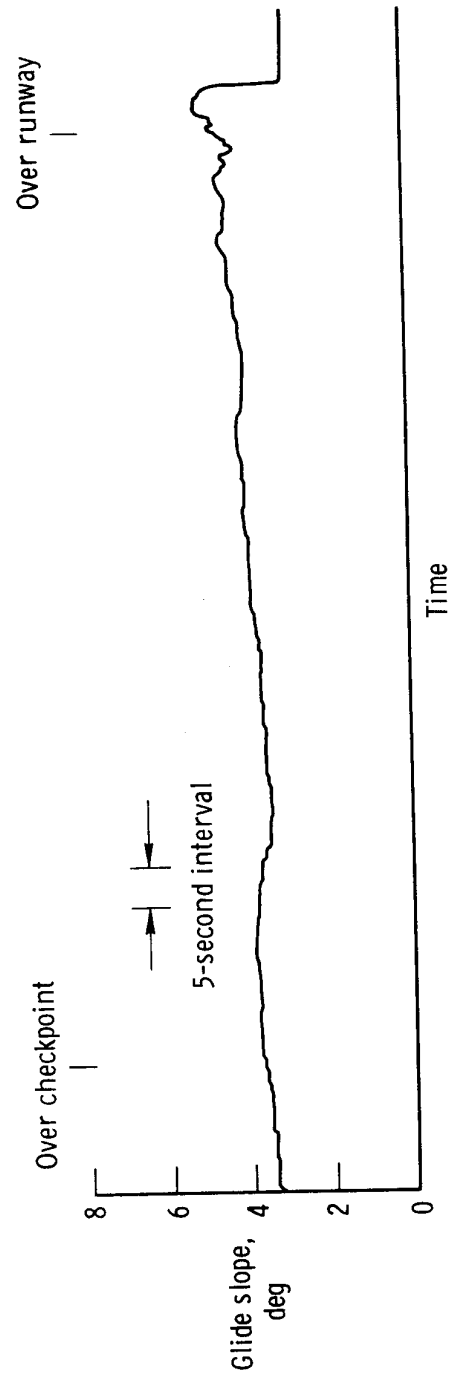


Figure 7. Time history of a typical approach made using the diamond.

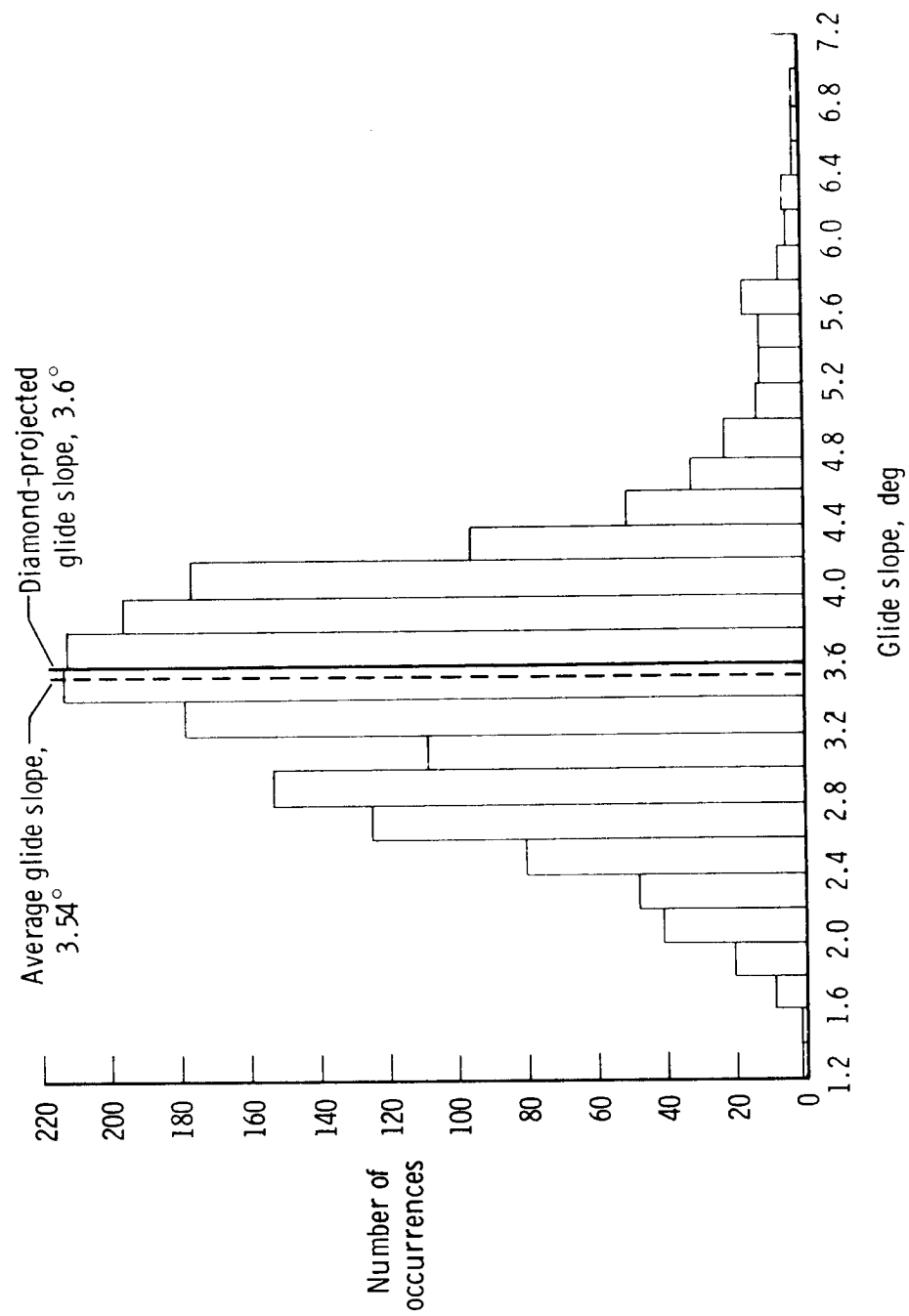


Figure 8. Histogram of glide-slope position for approaches made with the diamond.

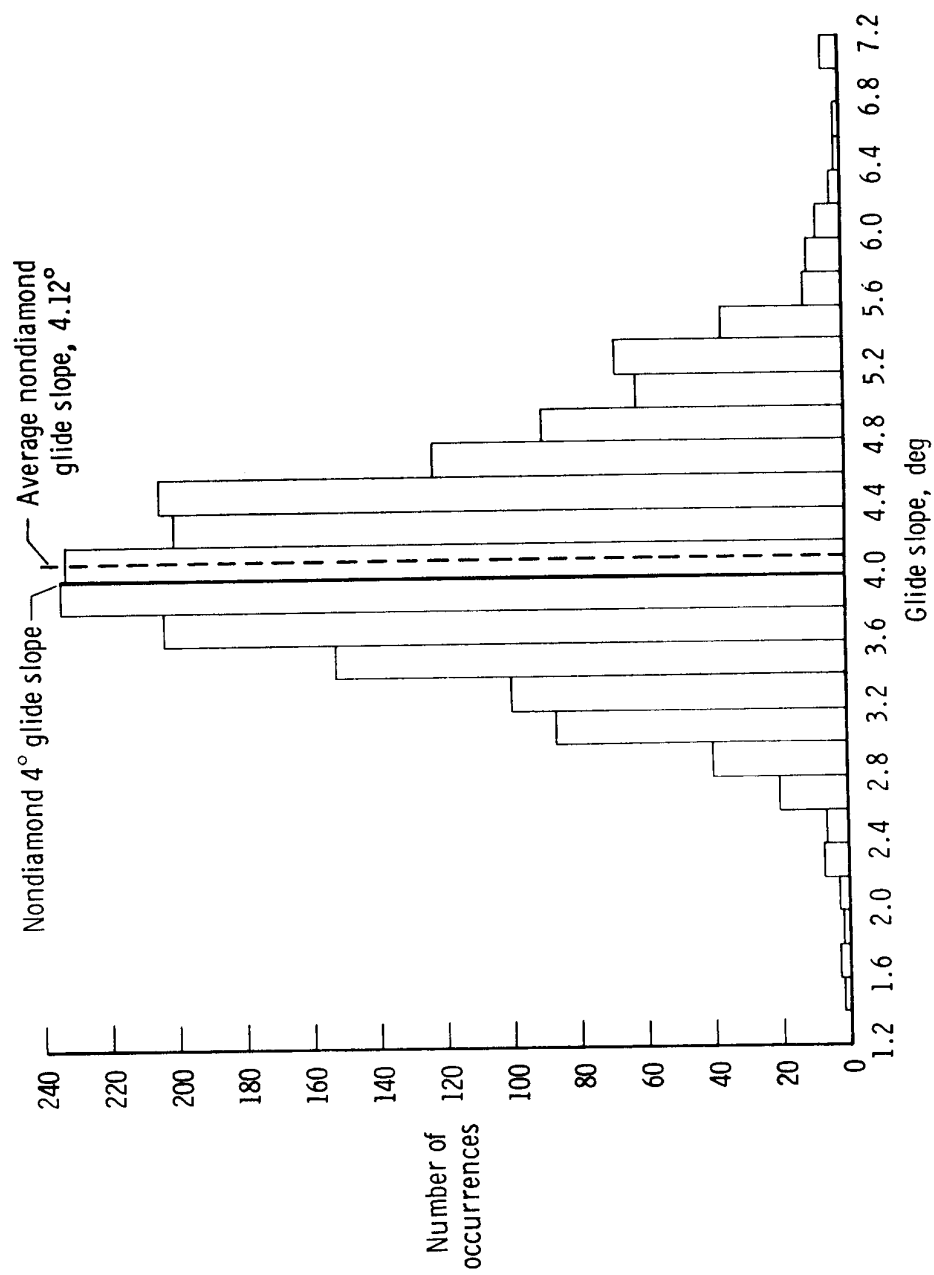


Figure 9. Histogram of glide-slope position for approaches made without the diamond.